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Matsui et al.

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(54) **LIQUID CRYSTAL DISPLAY DEVICE**

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G02F 1/1339 (2006.01)

G02F 1/1343 (2006.01)

(52) **U.S. Cl.**

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(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,259,503 B1 * 7/2001 Watanabe et al. 349/141
6,704,082 B2 * 3/2004 Tomioka et al. 349/123
8,018,540 B2 * 9/2011 Shin et al. 349/38
2012/0169985 A1 * 7/2012 Kim et al. 349/139
2012/0257156 A1 * 10/2012 Hiratsuka et al. 349/143

2013/0016314 A1 * 1/2013 Itou G02F 1/13394 349/106

2013/0265534 A1 * 10/2013 Hiratsuka G02F 1/134363 349/139

2013/0280661 A1 * 10/2013 Ishigaki G03F 7/20 430/319

2015/0085232 A1 * 3/2015 Hiratsuka G02F 1/134363 349/110

FOREIGN PATENT DOCUMENTS

CN 102879955 A 1/2013

JP 6-214244 8/1994

JP H09-185076 A 7/1997

(Continued)

OTHER PUBLICATIONS

English translation of JP 2002-229029A, Title: Liquid Crystal Display and Method for Manufacturing the Same, Author: Taniguchi Koji; Date of publication: Aug. 14, 2002.*

Chinese Office Action dated on Nov. 26, 2015, for corresponding Chinese Patent Application No. 201310545904.8.

(Continued)

Primary Examiner — Dung Nguyen

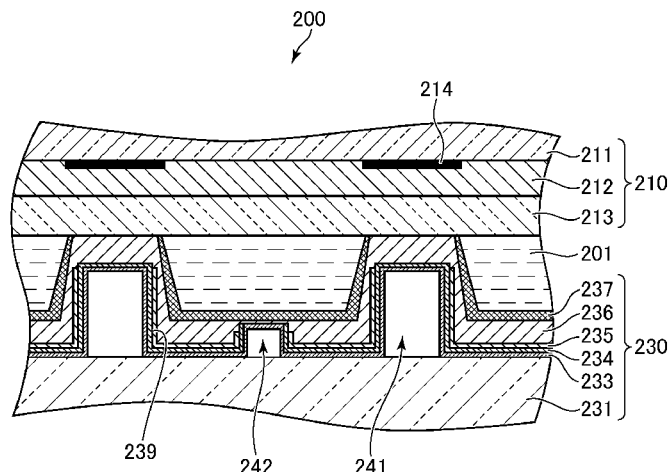
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(57) **ABSTRACT**

A liquid crystal display device includes a liquid crystal composition, a thin film transistor substrate as an insulation substrate on which a thin film transistor for controlling the orientation of the liquid crystal composition is provided, and a color filter substrate which seals the liquid crystal composition between itself and the thin film transistor substrate and controls a wavelength region of the transmitted light. The thin film transistor substrate includes a projection part extending from the thin film transistor substrate to the color filter substrate side, and a wall-like electrode on a wall surface of the projection part, which is one electrode for controlling the orientation of the liquid crystal composition. An insulation film and an orientation film are sequentially laminated on the wall-like electrode continuously from a surface parallel to a substrate surface.

3 Claims, 11 Drawing Sheets



(56)

References Cited

OTHER PUBLICATIONS

FOREIGN PATENT DOCUMENTS

JP 2000-347216 A 12/2000
JP 2002229029 A * 8/2002

Office Action from the Japanese Patent Office dated Feb. 9, 2016,
for Japanese Patent Application No. 2012-245135.

* cited by examiner

FIG. 1

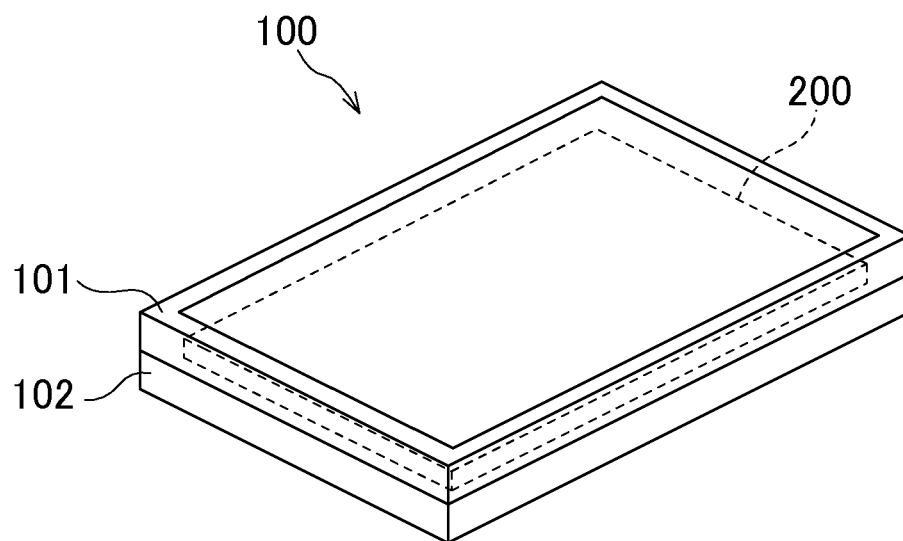


FIG. 2

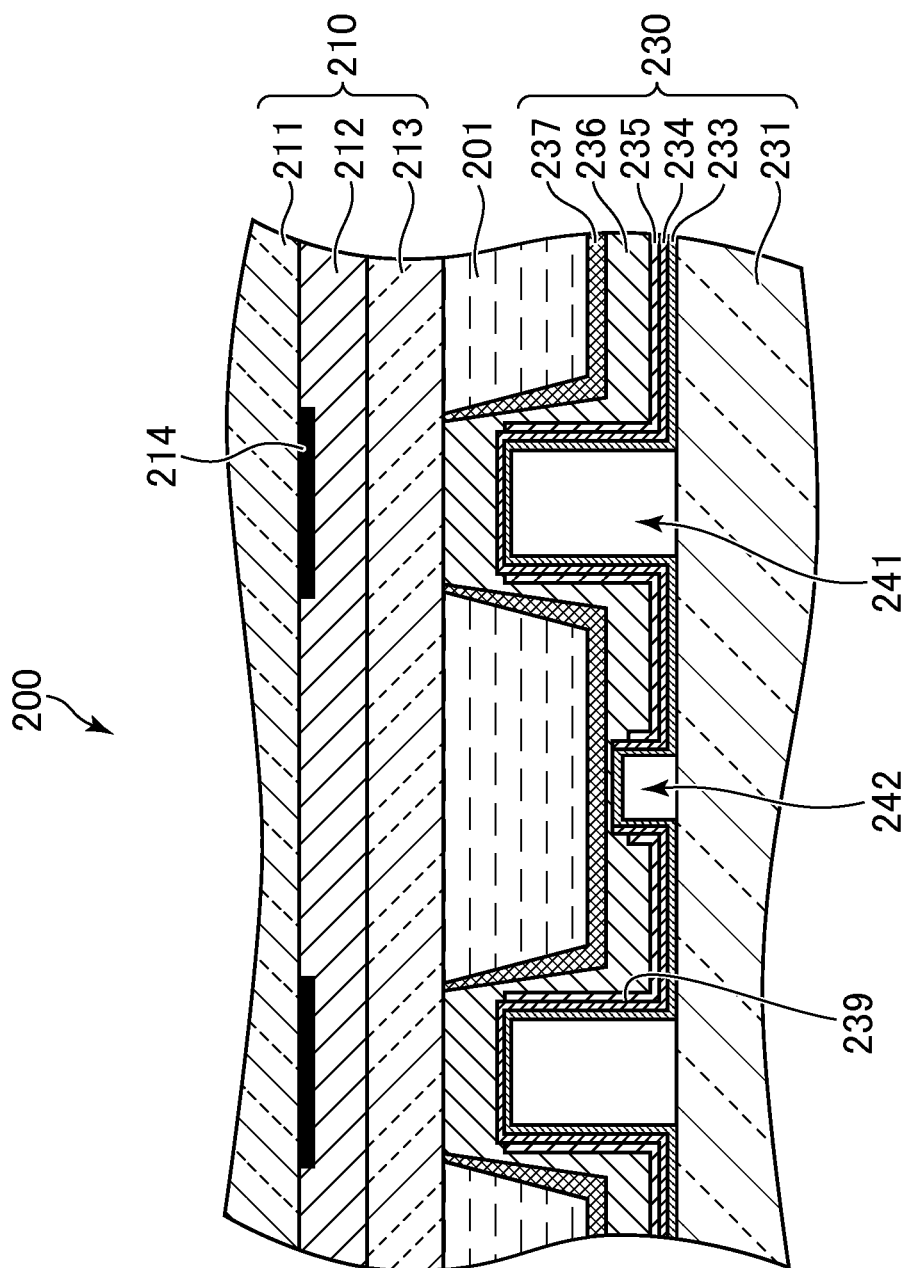


FIG.3

FILM FORMATION SEQUENCE	KIND OF FILM
1	MoW
2	SiN
3	ORGANIC INSULATION FILM
4	TRANSPARENT ELECTRODE FILM
5	SiN
6	TRANSPARENT ELECTRODE FILM
7	PAS
8	POLYIMIDE

FIG. 4

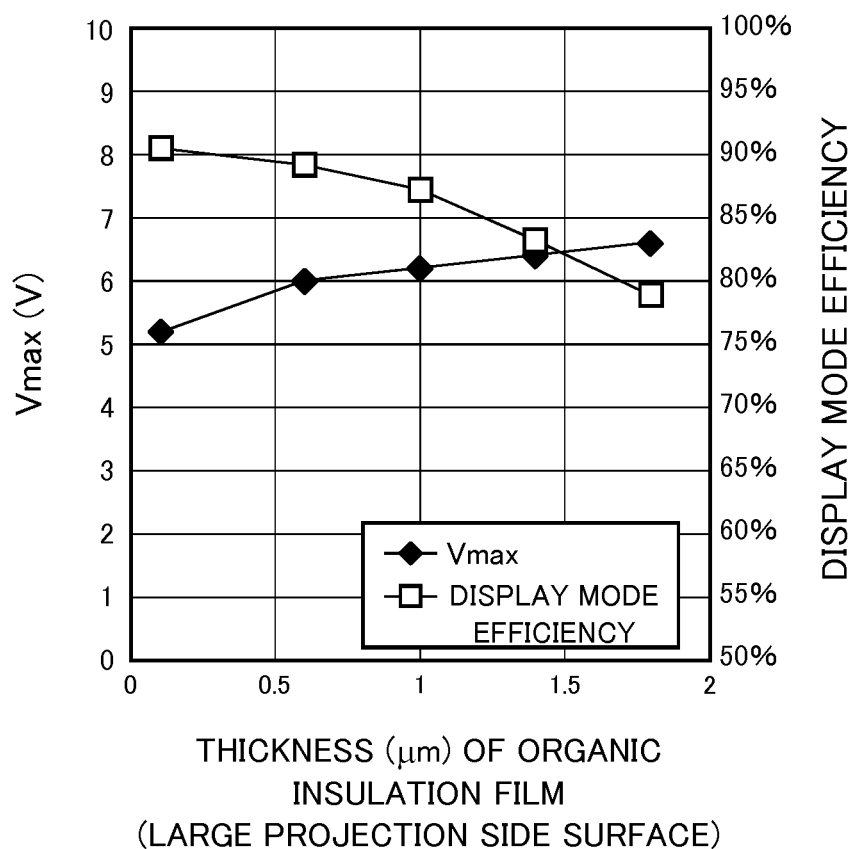


FIG. 5

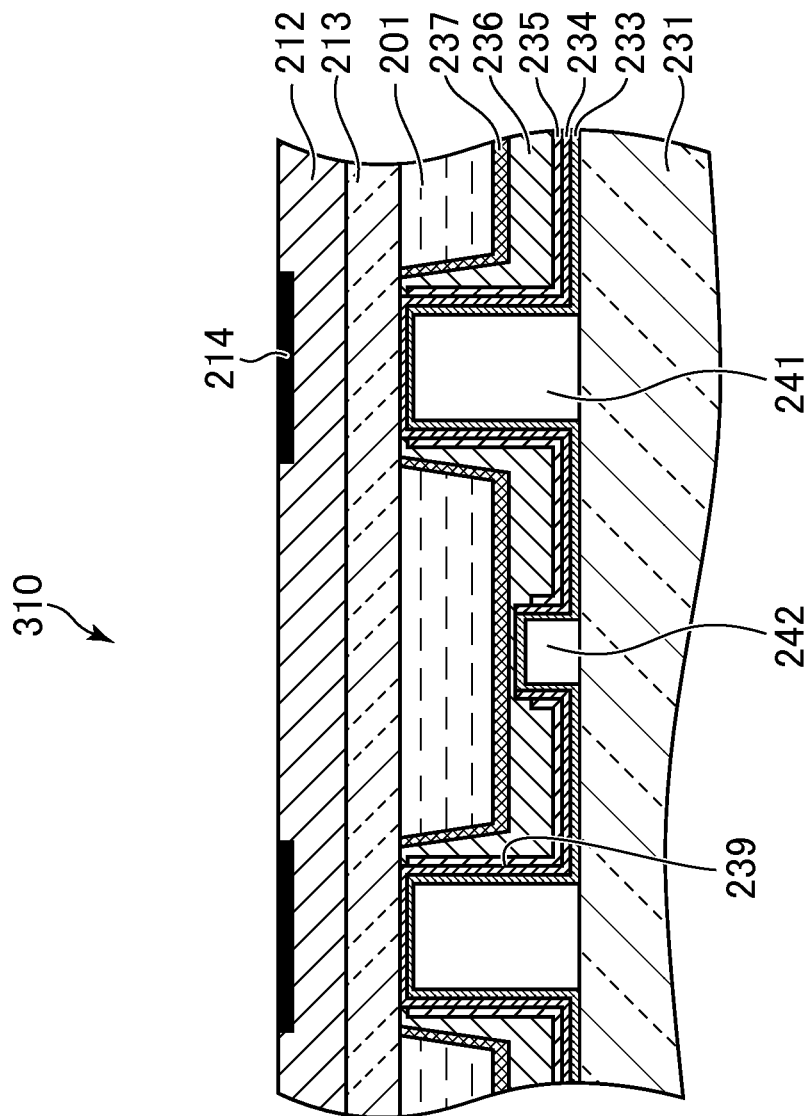


FIG. 6

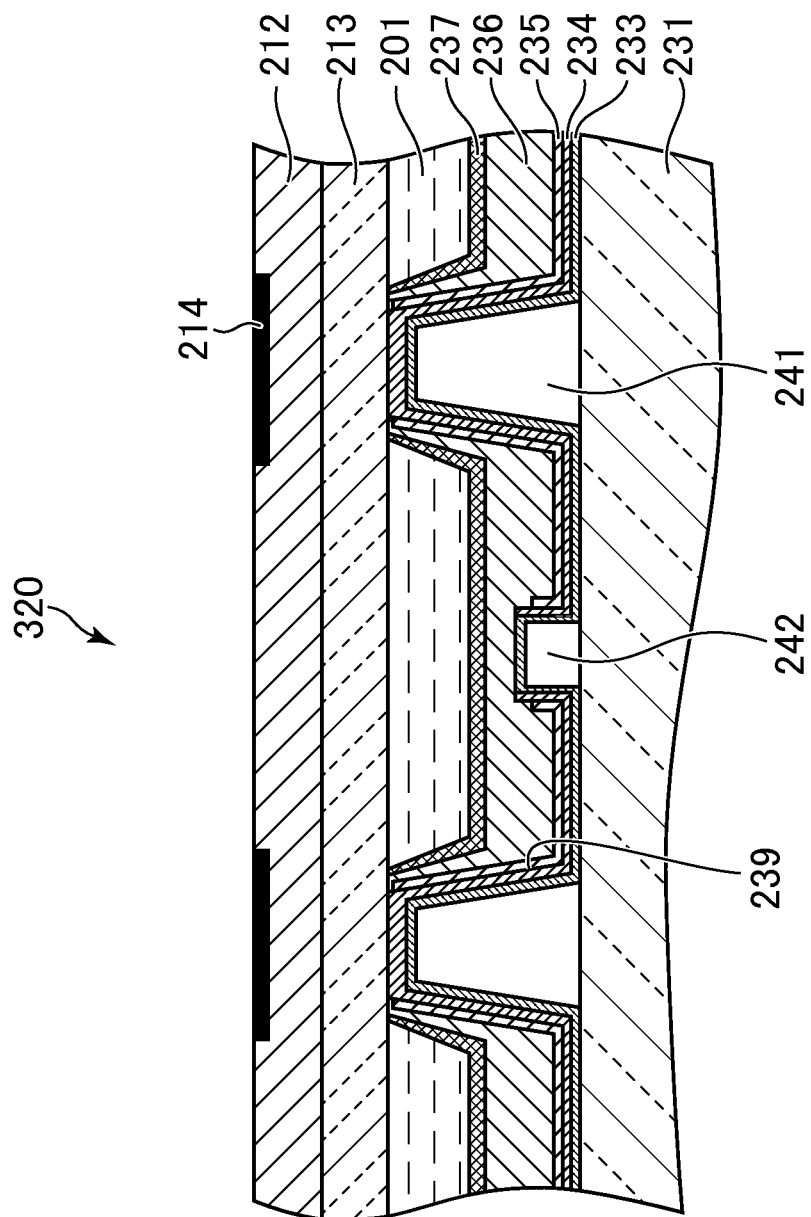


FIG. 7

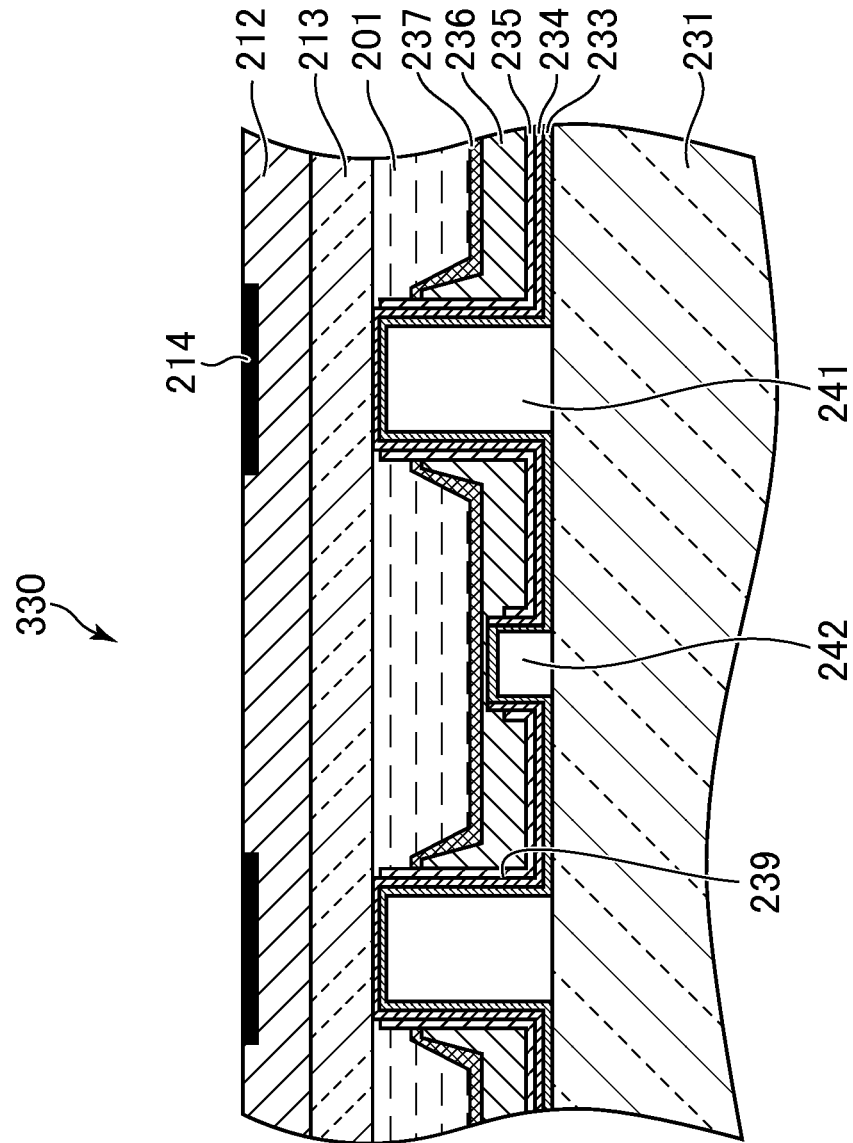


FIG. 8

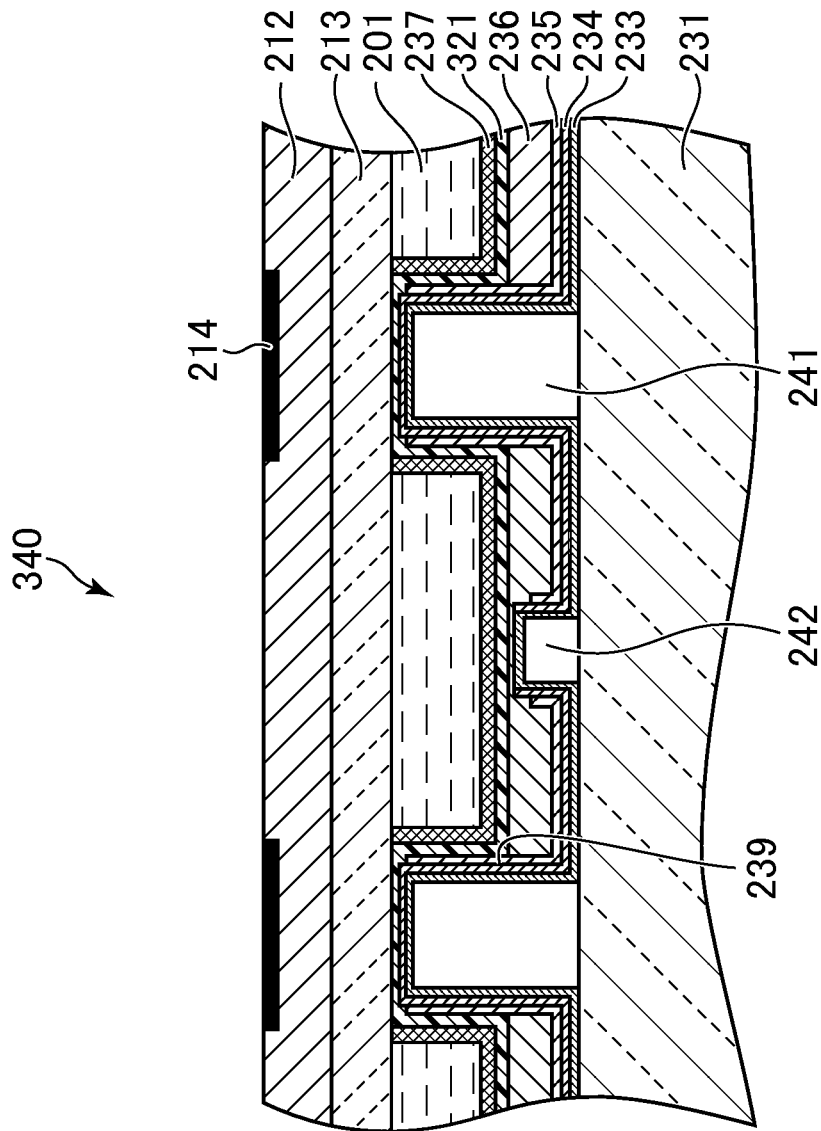


FIG.9

DISPLAY MODE EFFICIENCY	KIND OF FILM
1	MoW
2	SiN
3	ORGANIC INSULATION FILM
4	TRANSPARENT ELECTRODE FILM
5	SiN
6	TRANSPARENT ELECTRODE FILM
7	PAS
8	SiN
9	POLYIMIDE

FIG.10

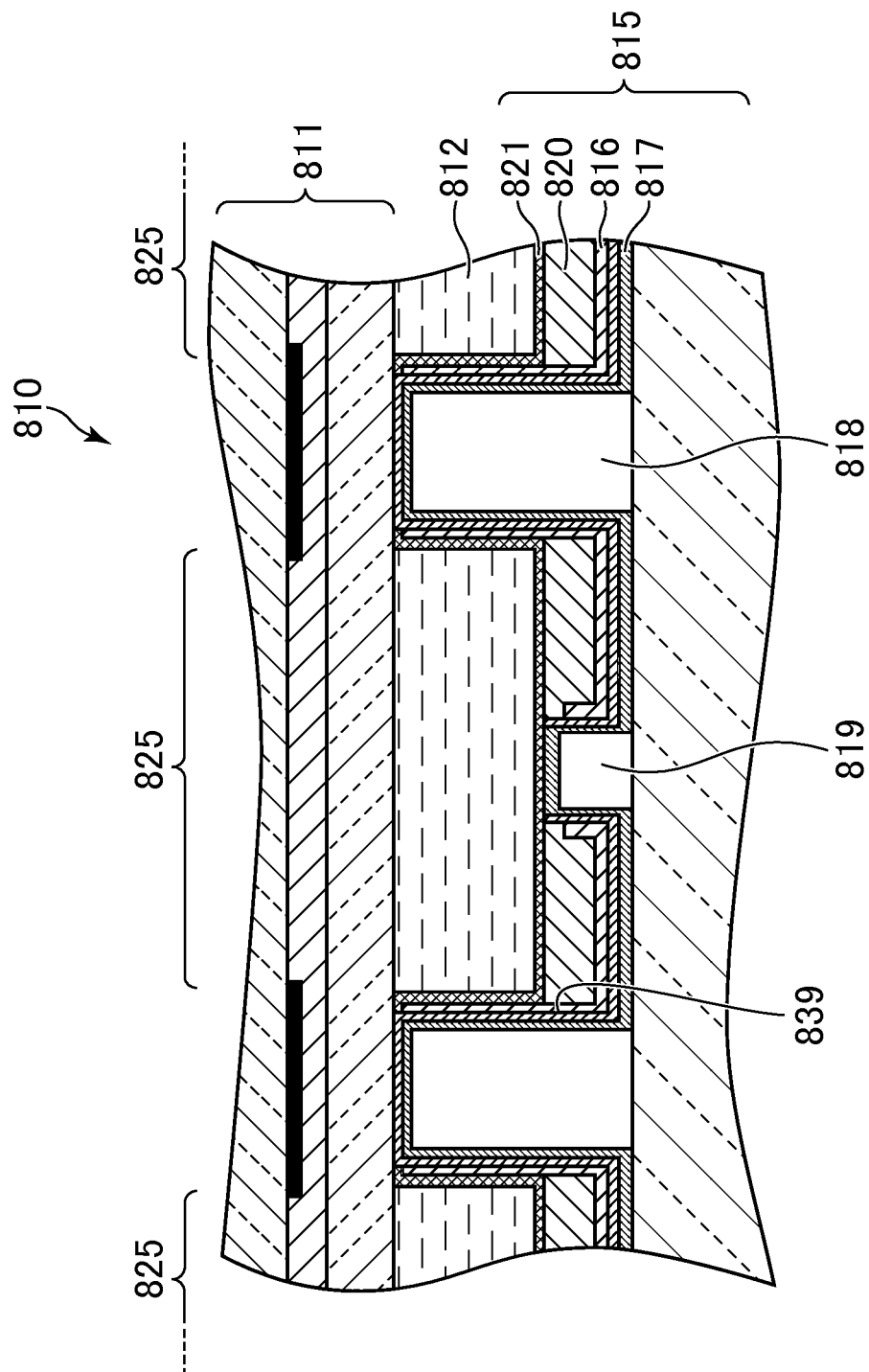
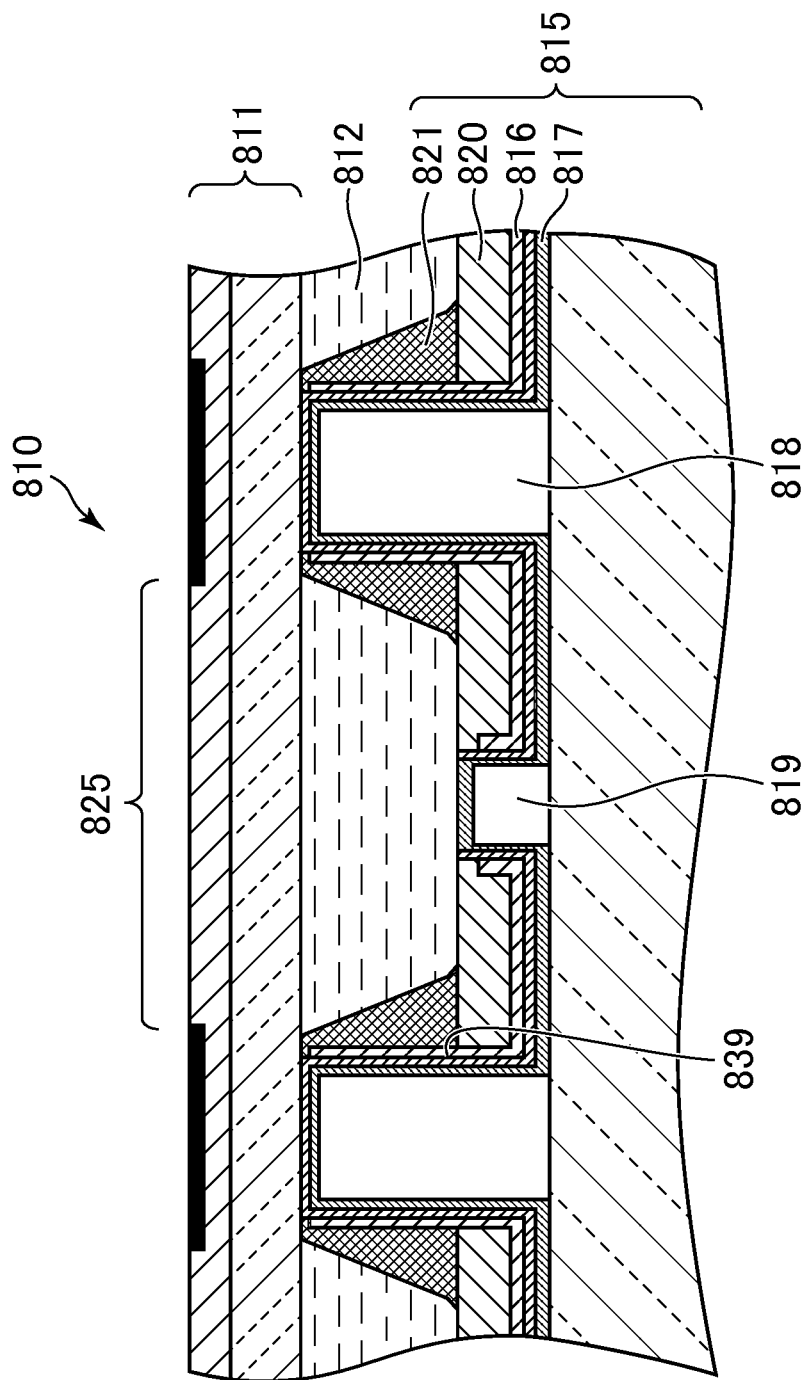


FIG.11



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LIQUID CRYSTAL DISPLAY DEVICE**CROSS-REFERENCE TO RELATED APPLICATION**

The present application claims priority from Japanese application JP2012-245135 filed on Nov. 7, 2012, the content of which is hereby incorporated by reference into this application.

BACKGROUND OF THE INVENTION**1. Field of the Invention**

The present invention relates to a liquid crystal display device.

2. Description of the Related Art

A liquid crystal display device is widely used as a display device of an information communication terminal such as a computer or of a television receiver. The liquid crystal display device is such a device that orientation of a liquid crystal composition sealed between two substrates is changed by change of an electric field, and an image is displayed by controlling a transmission degree of light passing through the two substrates and the liquid crystal composition.

JP 6-214244 A discloses a wall-like electrode in which the film thickness of an electrode portion for changing an electric field is formed to be thicker than that of the other portion, and the electric field is formed by an electrode formed on the side wall surface of the thick portion.

SUMMARY OF THE INVENTION

The wall-like electrode as disclosed in JP 6-214244 A is effective in forming a uniform electric field in a pixel. For example, when white display is performed in a normally black liquid crystal display device, the uniform electric field is formed, so that light transmittance can be increased. However, at the time of black display in which voltage is not applied to the electrode, there is a fear that light leakage occurs and contrast decreases.

The invention is made in view of the above circumstances, and an object thereof is to provide a liquid crystal display device in which display can be appropriately performed even when voltage is not applied to a wall-like electrode and contrast is high.

According to the invention, a liquid crystal display device includes a liquid crystal composition whose orientation is controlled to change an amount of transmitted light, a thin film transistor substrate as an insulation substrate in which a thin film transistor for controlling the orientation of the liquid crystal composition is provided, and a color filter substrate which seals the liquid crystal composition in a space with the thin film transistor substrate and controls a wavelength region of the transmitted light. The thin film transistor substrate includes a projection part extending from the thin film transistor substrate to the color filter substrate side, and a wall-like electrode on a wall surface of the projection part, which is one electrode for controlling the orientation of the liquid crystal composition. An insulation film and an orientation film are sequentially laminated on the wall-like electrode continuously from a surface parallel to a substrate surface.

Besides, in the liquid crystal display device, the wall-like electrode maybe a pixel electrode to which a voltage corresponding to a gradation value of each pixel is applied, and a common electrode as a counter electrode of the pixel

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electrode is an electrode provided in parallel to the substrate surface of the thin film transistor substrate.

Besides, in the liquid crystal display device, the projection part may be a spacer to form an interval between the thin film transistor substrate and the color filter substrate.

Besides, in the liquid crystal display device, the insulation film may be one of an organic insulation film and an inorganic insulation film, and the inorganic insulation film may be a SiN film.

Besides, in the liquid crystal display device, a thickness of the insulation film may be 0.05 μm to 0.5 μm .

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a view schematically showing a liquid crystal display device of a first embodiment of the invention.

FIG. 2 is a view schematically showing a part of a section of a pixel of a liquid crystal display panel of FIG. 1.

FIG. 3 is a table showing a film formation sequence of films formed on a thin film transistor of a thin film transistor substrate of FIG. 2.

FIG. 4 is a graph showing a drive voltage required for display and a display mode efficiency with respect to the thickness of an organic insulation film at a side portion of a large projection.

FIG. 5 is a view showing a liquid crystal display panel of modified example 1 of the first embodiment in the same viewing field as that of FIG. 2.

FIG. 6 is a view showing a liquid crystal display panel of modified example 2 of the first embodiment in the same viewing field as that of FIG. 2.

FIG. 7 is a view showing a liquid crystal display panel of modified example 3 of the first embodiment in the same viewing field as that of FIG. 2.

FIG. 8 is a view schematically showing a part of a section of a pixel of a liquid crystal display panel of a liquid crystal display device of a second embodiment.

FIG. 9 is a table showing a film formation sequence of films formed on a thin film transistor of a thin film transistor substrate of FIG. 8.

FIG. 10 is a view showing a liquid crystal display panel including a wall-like electrode of a comparative example of the invention.

FIG. 11 is a view showing a liquid crystal display panel including a wall-like electrode of a comparative example of the invention.

DETAILED DESCRIPTION OF THE INVENTION

First, a normally black liquid crystal panel **810** including a wall-like electrode of a comparative example of the invention shown in FIG. 10 will be described. FIG. 10 schematically shows an example of a section of a pixel of the liquid crystal panel **810**. As shown in this drawing, the liquid crystal panel **810** includes a color filter substrate **811**, a thin film transistor substrate **815**, and a liquid crystal composition **812** sandwiched and sealed between the substrates. The thin film transistor substrate **815** includes a large projection **818** formed between pixels **825**, and a small projection **819** formed in the pixel **825**, and further includes a pixel electrode **816** having a wall-like electrode **839** which is provided on a wall surface of the large projection **818** and forms an electric field acting on the liquid crystal composition **812**, and a common electrode **817** which is a counter electrode of the pixel electrode **816**, is provided on an upper surface of the small projection **819** and forms an electric field acting on

the liquid crystal composition **812**. In each of the pixels **825**, an organic insulation film **820** is formed so as to cover the pixel electrode **816**. As shown in this drawing, an orientation film **821** is desirably uniformly formed on the organic insulation film **820**, the wall-like electrode **839**, and the common electrode **817** on the upper surface of the small projection **819** so as to have a uniform thickness on the surface which the liquid crystal composition **812** contacts.

However, according to the research of the inventors, it was found that when the orientation film **821** was formed on the films laminated as described above, the orientation film **821** was mainly formed on the wall-like electrode **839** as shown in FIG. 11 and was hardly formed on the organic insulation film **820** between the walls because of a difference in surface energy between the material of the organic insulation film **820** and the material of the pixel electrode **816**. When the orientation film **821** is unevenly formed as shown in FIG. 11, since the orientation of the liquid crystal composition **812** becomes worse in an area between the walls where the orientation film is thin, light leakage at the time of black display is liable to occur, and further, the light leakage at the time of black display is liable to occur also by burning due to application of a signal voltage. Accordingly, contrast in image display is decreased.

Hereinafter, first and second embodiments of the invention will be described with reference to the drawings. Incidentally, in the drawings, the same or like components are denoted by the same reference numerals and a duplicate description is omitted.

First Embodiment

FIG. 1 schematically shows a liquid crystal display device **100** of the first embodiment of the invention. As shown in this drawing, the liquid crystal display device **100** includes a liquid crystal display panel **200** fixed to be sandwiched between an upper frame **101** and a lower frame **102**. Here, in this embodiment, a description is made on an example of a so-called normally black liquid crystal display panel in which black display is performed when voltage is not applied to an electrode. However, no limitation is made to this, and the invention can be applied also to a normally white liquid crystal display panel.

FIG. 2 is a view schematically showing a part of a section of a pixel of the liquid crystal display panel **200**. As shown in this drawing, the liquid crystal display panel **200** includes a color filter substrate **210**, a thin film transistor substrate **230**, and a liquid crystal composition **201** sandwiched therebetween. The color filter substrate **210** is provided with a black matrix **214** formed on a glass insulation substrate **211** and for preventing light leakage from adjacent pixels, a color filter **212** to determine a wavelength region of transmitted light, and an overcoat layer **213** to protect them.

The thin film transistor substrate **230** includes a glass substrate **231** on which a not-shown thin film transistor is formed. A large projection **241** which is made of an organic insulation film, is formed between the pixels and extends from a substrate surface, and a small projection **242** which is formed in the pixel and extends from the substrate surface are provided on the thin film transistor through an insulation film. Further, the thin film transistor substrate **230** includes a common electrode **233** which is formed on the whole surface of a display region so as to cover the large projection **241** and the small projection **242** and is made of a transparent electrode of, for example, ITO, an organic insulation film **234** which is made of, for example, SiN and is for insulation from an after-mentioned pixel electrode **235**, the pixel electrode **235** which includes at least a wall-like electrode **239** formed on a wall surface of the large projec-

tion **241** and is made of a transparent electrode of, for example, ITO, an organic insulation film **236** which is not formed or is thinly formed on the common electrode **233** formed on the upper surface of the small projection **242** and is formed on the large projection **241** and its wall surface, and an orientation film **237** formed along the surface of the organic insulation film **236**.

Here, as shown in FIG. 2, in this embodiment, the orientation film **237** is not formed on the upper surface of the large projection **241**, and the organic insulation film **236** is formed to contact the color filter substrate **210**. By this, the large projection **241** and the film formed on the upper surface function also as a spacer to determine an interval between the thin film transistor substrate **230** and the color filter substrate **210**. However, no limitation is made to this embodiment, and the orientation film **237** may be formed on the upper surface of the large projection **241**, or the liquid crystal composition **201** maybe disposed between the large projection **241** and the color filter substrate **210**.

FIG. 3 is a table showing a film formation sequence of films formed on the thin film transistor of the thin film transistor substrate **230** of the embodiment. As shown in this table, after a part of wiring of the thin film transistor is formed of MoW, a SiN film as the insulation film is formed, and the large projection **241** and the small projection **242** are formed of organic insulation films thereon. Thereafter, the common electrode **233** is formed of a transparent electrode film of ITO or the like, and the inorganic insulation film **234** is formed of SiN thereon. Further, after a transparent electrode film of ITO or the like, which becomes the pixel electrode **235**, is formed, the organic insulation film **236** is formed, and a polyimide film which becomes the orientation film **237** is formed thereon by a photo-orientation process. Here, the film formation process of each film includes a process of patterning by photolithography or the like according to the need.

FIG. 4 is a graph showing a drive voltage required for display and a display mode efficiency corresponding to a light transmittance at the time of white display with respect to the thickness of the organic insulation film **236** at a side portion of the large projection **241**. As shown in this graph, it is understood that as the thickness of the organic insulation film **236** increases, the display mode efficiency decreases, the required drive voltage V_{max} increases, and power consumption increases. Based on the detailed examination of the inventors, it is desirable that the film formation is performed in a range of $0.05\ \mu\text{m}$ to $0.5\ \mu\text{m}$ in which less influence is exerted on these values.

As described above, according to this embodiment, the insulation film is formed also on the wall surface of the large projection continuously from the surface parallel to the substrate surface in the pixel, and the orientation film is formed thereon. Thus, the orientation film is formed also on the surface parallel to the substrate surface, and appropriate display can be performed even when a voltage is not applied to the wall-like electrode, for example, at the time of black display of a normally black liquid crystal display device or at the time of white display of a normally white liquid crystal display device. By this, the contrast of the display device can be improved.

FIG. 5 is a view showing a liquid crystal display panel **310** of modified example 1 of the first embodiment in the same viewing field as that of FIG. 2. As shown in this drawing, in the modified example 1, an organic insulation film **236** is not formed on an upper surface of a large projection **241**. Also in the structure as stated above, the same effect as that of the first embodiment can be obtained.

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FIG. 6 is a view showing a liquid crystal display panel 320 of modified example 2 of the first embodiment in the same viewing field as that of FIG. 2. As shown in this drawing, in the modified example 2, in addition to the structure of the modified example 1, a large projection 241 is taper-shaped. By the structure as stated above, the same effect as that of the first embodiment can be obtained, and further, an organic insulation film 236 and an orientation film 237 can be more uniformly formed on the side surface of the large projection 241.

FIG. 7 is a view showing a liquid crystal display panel 330 of modified example 3 of the first embodiment in the same viewing field as that of FIG. 2. As shown in this drawing, in the modified example 3, an organic insulation film 236 is not formed on a wall surface upper portion of a large projection 241. Even in the structure as stated above, since the organic insulation film 236 is formed on a wall surface lower portion of the large projection 241 where an orientation film 237 is liable to stay. Thus, the orientation film 237 is uniformly formed in a pixel, and the same effect as that of the first embodiment can be obtained.

Second Embodiment

Since the whole structure of a liquid crystal display device of the second embodiment is the same as the whole structure of the liquid crystal display device 100 of the first embodiment shown in FIG. 1, the description thereof is omitted. FIG. 8 is a view schematically showing a part of a section of a pixel of a liquid crystal display panel 340 of the liquid crystal display device of the second embodiment. A different point from the liquid crystal display panel 200 of the first embodiment is that an organic insulation film 236 is merely formed around a large projection 241 so as to have almost the same height as that of a small projection 242, and an inorganic insulation film 321 made of, for example, SiN is formed so as to cover the organic insulation film 236 and the large projection 241. An orientation film 237 is formed on the inorganic insulation film 321 similarly to the first embodiment.

Also in the case of this structure, similarly to the first embodiment, the insulation film is formed also on the wall surface of the large projection continuously from the surface parallel to the substrate surface in a pixel, and the orientation film is laminated thereon. Thus, the orientation film is formed also on the surface parallel to the substrate surface, and appropriate display can be performed even when a voltage is not applied to a wall-like electrode, for example, at the time of black display of a normally black liquid crystal display device or at the time of white display of a normally white liquid crystal display device. By this, the contrast of the display device can be improved.

Further, since the inorganic insulation film 321 can be formed by a method such as CVD (Chemical Vapor Deposition), the film can be formed to be thinner than the organic insulation film. Thus, as shown in the graph of FIG. 4, the above effect can be obtained without influencing the display mode efficiency and the drive voltage V_{max} .

FIG. 9 is a table showing a film formation sequence of films formed on a thin film transistor of a thin film transistor substrate of the liquid crystal display panel 340 of the second embodiment. A different point from FIG. 3 is that the SiN film of the inorganic insulation film 321 is formed at the eighth step of the film formation sequence. Since the others are the same as those of FIG. 3, the description thereof is omitted.

In the foregoing embodiments, although the common electrode is provided only on the thin film transistor sub-

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strate side, for example, the common electrode may be provided also on the color filter substrate side through the liquid crystal composition.

Besides, in the foregoing embodiments, although the pixel electrode is arranged in the wall-like electrode, and the common electrode is arranged at the center in the pixel of the thin film transistor substrate, the arrangement of the pixel electrode and the common electrode may be reverse to this.

Besides, in the foregoing embodiments, although the insulation film and the orientation film are directly formed on the wall-like electrode, another layer may be formed between the wall-like electrode and the insulation film.

While there have been described what are at present considered to be certain embodiments of the invention, it will be understood that various modifications may be made thereto, and it is intended that the appended claim cover all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A liquid crystal display device comprising:

- a liquid crystal composition whose orientation is controlled to change an amount of light which travels through pixels;
- a thin film transistor substrate as an insulation substrate on which a thin film transistor for controlling the orientation of the liquid crystal composition is provided; and
- a color filter substrate which seals the liquid crystal composition in a space with the thin film transistor substrate and controls a wavelength region of the transmitted light, wherein

the thin film transistor substrate has the pixels, and every one of the pixels comprises

- a large projection having a large wall surface and a small projection having a small wall surface, and extending from the thin film transistor substrate to the color filter substrate side,
- a planar portion between the large projection and the small projection,
- a common electrode continuously formed on the large projection, the small projection, and the planar portion,
- a first insulation film on the common electrode,
- a pixel electrode formed on the common electrode through the first insulation film, the pixel electrode formed above the large wall surface, the small wall surface, and the planar portion,
- a second insulation film, which is an organic insulation film on the pixel electrode over the large projection, the small projection, and the planar portion, and
- an alignment film formed on the pixel electrode through the second insulation film,
- the second insulation film having a greater thickness above the planar portion than the small projection.

2. The liquid crystal display device according to claim 1, wherein the large projection is a spacer to form an interval between the thin film transistor substrate and the color filter substrate.

3. The liquid crystal display device according to claim 1, wherein a thickness of the second insulation film above the large wall surface is 0.05 μm to 0.5 μm .

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